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# Global Climate Change: An Opponent's Notes

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## Introduction

This is intended as a response to the climate change paper by William Cline (2004). Climate change is a problem that requires an unprecedented degree of international consensus, and its consequences must be considered over a time horizon of unprecedented length. It would be a serious mistake to underestimate the difficulty of achieving a consensus. There are serious uncertainties on both the science and the economics. Cline has offered a useful challenge, but – in my judgment – it overstates the immediacy of the problem. In the allocation of limited global resources, it does not warrant as much effort as dealing with poverty and disease in the developing nations.

Cline's paper deals with three policy strategies: (1) an optimal carbon tax (or regional quotas); (2) the Kyoto protocol; and (3) a value-at-risk approach. Because of space limitations, I will deal with only the first of these strategies. There is widespread disagreement over the Kyoto agreement. Despite the European consensus, neither the U.S. nor Russia have agreed to ratify this agreement. For emissions control to be effective, eventually the developing nations will also have to join in. This is why an optimal carbon tax (or regional quotas) provides a more meaningful frame of reference than Kyoto.

Why not consider the value-at-risk approach? This is an exceedingly risk-averse criterion. If it is good to adopt a 95% threshold for the climate sensitivity parameter, why not 99%? Or an even higher value? Moreover, this criterion discards one of the principal parameters of dynamic decision analysis. It neglects the "act, then learn" features of the problem. Yes, there is uncertainty, but eventually there is some resolution of this uncertainty. We may all be willing to agree that the climate sensitivity parameter could be as high as 9.5º C. But if the effects turn out to be this dramatic, it should not take very many years for us to reach a consensus on this aspect of the debate. Value-at-risk may be appropriate in considering financial risks, but it seems to be the wrong criterion for evaluating measures that might be employed to combat global climate change. It distracts us from taking more meaningful steps for dealing with the problem.

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**Benefit-cost analysis**

Cline provides a useful introduction to benefit-cost analysis in the area of global climate change. I have no real disagreement with his description of the components of costs and benefits. And I agree that there is very little difference between a policy in which nations are persuaded to adopt a uniform global tax – and a policy in which regional emission quotas are assigned to individual nations, and there is "banking", "borrowing" and international trade in these quota rights. In both cases, there is full "when" and "where" flexibility. That is, there is a market test for when and where emissions are to be reduced. Neither Cline nor I would disagree with the importance of arriving at an efficient allocation of resources. There is the further issue of equity, but this is where we need the participation of some imaginative political scientists.

My principal concern is that Cline has advocated a discounting strategy that is unduly alarmist. Moreover, by presenting a global approach through the DICE model, he has ignored the priorities of individual developing countries. For this reason, I will quantify my critique in terms of MERGE, a model for evaluating regional and global effects of greenhouse gas emission reductions. This model represents joint work with Richard Richels and others. For details, see: www.stanford.edu/group/MERGE. A computer listing is available at that website. MERGE contains submodels governing:

the domestic and international economy
energy-related emissions of greenhouse gases
non-energy emissions of ghg's
global climate change

Each region's domestic economy is viewed as though it were a Ramsey-Solow model of long-term economic growth. The time paths of investment and consumption are strongly influenced by the choice of a "utility" discount rate. This in turn may be governed by a prescriptive or a descriptive viewpoint.

Energy-related emissions in MERGE are projected through a bottom-up perspective. Fuel demands are estimated through "process analysis" and a top-down production function of the inputs of capital, labor, electric and non-electric energy.

Each period's emissions are translated into global concentrations and in turn to the impacts on mean global indicators such as temperature change. The MERGE model may be operated in a "cost-effective" mode - that is, supposing that international negotiations lead to a time path of emissions that satisfies a constraint on concentrations or on temperature change. The model may also be operated in a "benefit-cost" mode - choosing a time path of emissions that maximizes the discounted utility of consumption, after making allowance for the disutility of abrupt climate change.

Individual geopolitical regions are distinguished in the MERGE model. Abatement choices are distinguished by "where" (in which region?), "when" (in which time period?)

and "what" (which greenhouse gas to abate?). There may be tradeoffs between equity and efficiency in these choices.

**Population and regional GDP projections**

Greenhouse emissions are *not* proportional to population and GDP, but they can be quite sensitive to these projections. For this purpose, we have used what we believe to be a middle-of-road projection of the global population – assuming that it will rise from 6 billion people in 2000 to 10 billions in 2100, and that it will stabilize thereafter. Virtually all of this growth will take place in the developing countries.

Separate projections are provided for each of nine regions. It is useful to draw a distinction between the four high-income regions: USA, Western Europe, Japan, Canada and Australia-New Zealand; and the five low-income regions: Eastern Europe and former Soviet Union, China, India, Mexico and OPEC nations and ROW (rest of world). The model employs ten-year time steps extending from 2000 through 2200. To reduce "horizon effects", we shall only report the years through 2150. (See Figure 1.)

Population projections may be debatable, but there are even more controversies with respect to productivity and per capita GDP growth. Through 2020, we have taken over these projections from the "reference case" defined by the Energy Information Administration (2003). Thereafter, we have extrapolated by using logistic functions. The initial point is the EIA projection for 2020. Each of these logistic functions converges to the identical asymptote. The "limit to growth" is $200 thousand per capita, but this limit is not reached for several centuries. This value is astronomical in comparison with today's incomes in India, China and other low-income nations. It was chosen so that there would not be an immediate decline in the growth rate of the high-income countries during the next two centuries.

For each of the nine regions, the third point along the logistic curve is an arbitrary individual estimate of the per capita GDP in the year 2100. These values were chosen so as to allow for a smooth transition post-2020 – and a *partial* convergence of the low-income countries to those with high incomes by 2100. For example, the U.S. grows from $36 thousands in 2000 to $115 thousand by 2100. India grows rapidly (from $0.5 to $25 thousands), but is still far behind the U.S. by the end of the century.

All dollar values here are expressed in dollars of 2000 purchasing power, and are shown at market exchange rates. If instead we had employed "purchasing power parity", there would have been much higher initial GDP values for the low-income nations, but lower growth rates of GDP and of emissions. With PPP, we have found only minor changes for the high-income nations.

**Market and non-market damages**

Typically, the benefits of slow climate change are expressed in terms of the damages avoided. When Nordhaus (1991) made his first efforts at quantification, the benefits were expressed in terms of avoiding crop losses, forestry damage, shoreline erosion, etc. For each of these sectors, it was possible to assign market values to the losses. There are prices for crops, timber and real estate. Later, it was discovered that some changes (e.g., CO2 fertilization) could even lead to modest gains in some of these areas. There is an emerging consensus that market damages are not the principal reason to be concerned over climate change.

The more worrisome issue is the type of damage for which there are no market values. The "non-market damages" include human health, species losses and catastrophic risks such as the shut-down of the thermohaline circulation in the Atlantic ocean. Here we must rely on imagination and introspection. We can be sure of only one thing. This type of loss is of far greater concern to high-income regions than to those with low incomes. Bangladesh has more reason to be concerned about typhoons than about Arctic ice flows.

In MERGE, we have tried to allow for both market and non-market damages, but have focused our attention on the latter. Many calculations have been based upon C.S., the climate sensitivity parameter. This is the equilibrium warming associated with a doubling of carbon concentrations over the pre-industrial level. A typical value for this parameter is an equilibrium warming of 2.5º C. For market damages, we have supposed that this amount of temperature rise would lead to GDP losses of only 0.25% in the high-income nations, and to losses of 0.50 % in the low-income nations. From 2050 onward, recall that only a small amount of global GDP will originate in agriculture, forestry and fishing. At higher or lower temperature levels than the C.S. of 2.5º, we have made the convenient assumption that market losses would be proportional to the temperature change.

For non-market damages, MERGE is based on the conservative proposition that expected losses would increase quadratically with the temperature rise. That is, there are only small discernible losses at the temperature level of 2000, but the losses from possible catastrophes could increase radically if we go to higher temperatures. Figure 3 shows the admittedly speculative estimates that are currently used in MERGE. Different numerical values are employed – depending upon the per capita income of the region at each point in time. These loss functions are based on two parameters that define willingness-to-pay to avoid a temperature rise: catt and hsx.

To avoid a 2.5º temperature rise, high-income countries might be willing to give up 2% of their GDP. (Why 2%? This is the total GDP component that is currently devoted by the U.S. to all forms of environmental controls – on solids, liquids and gases.) On Figure 3, this is expressed as an "economic loss factor" of 98% associated with a temperature rise of 2.5º. (The loss factor at 2.5º is circled on the two lower curves.) This factor represents the fraction of consumption that remains available for conventional uses by

households and by government. For high-income countries, the loss is quadratic in terms of the temperature rise. That is, in those countries, the hockey-stick parameter hsx = 1, and the loss factor is:

$$ELF(x) = [1 - (x/catt)^2]^{hsx}$$

where x is a variable that measures the temperature rise above its level in 2000, and catt is a catastrophic temperature parameter chosen so that the entire regional product is wiped out at this level. In order for ELF(2.5) = .98 in high-income nations, the catt parameter must be 17.7º C. This is a direct implication of the quadratic function.

What about low-income countries such as India? In those countries, the hsx exponent lies considerably below unity. It is chosen so that at a per capita income of $25 thousand, a region would be willing to spend 1% of its GDP so as to avoid a global temperature rise of 2.5º. (See loss factor circled on the middle curve.) At $50 thousand or above, India might be willing to pay 2%. And at $5 thousand or below, it would be willing to pay virtually nothing. To see how these parameters work out, consider the three functions shown on Figure 3. At all points of time, the U.S. per capita GDP is so high that ELF is virtually the identical quadratic function of the temperature rise. Now look at India. By 2100, India's per capita GDP has climbed to $25 thousand, and ELF is 99% at a temperature rise of 2.5º. In 2050, India's per capita GDP is still less than $4 thousands, and that is why its ELF remains virtually unity at that point – regardless of the temperature change.

Caveat: Admittedly, both catt and hsx are highly speculative parameters. With different numerical values, one can obtain alternative estimates of the willingness-to-pay to avoid non-market damages. One example will be given below. Although the numerical values are questionable, the general principle seems plausible. All nations might be willing to pay something to avoid climate change, but poor nations cannot afford to pay a great deal in the near future. Their more immediate priorities will be overcoming domestic poverty and disease.

We are now ready to incorporate the ELF functions into the maximand of MERGE. The maximand is the Negishi-weighted discounted utility (the logarithm) of consumption – adjusted for non-market damages:

$$\text{Maximand} = \sum_{rg} nwt_{rg} \sum_{pp} udf_{pp,rg} \cdot \log\left(ELF_{rg,pp} C_{rg,pp}\right)$$

where:

$nwt_{rg}$ = Negishi weight assigned to region rg - determined iteratively so that each region will satisfy an intertemporal foreign trade constraint

$udf_{pp,\,rg}$ = utility discount factor assigned to region rg in projection period pp

$ELF_{rg,pp}$ = economic loss factor assigned to region rg in projection period pp

$C_{rg,pp}$ = conventional measure of consumption (excluding non-market damages) assigned to region rg in projection period pp

**Prescriptive and descriptive views on the rate of return**

Consider a single region with a single good that may be used interchangeably for consumption and investment. For analytic purposes, it will be convenient to assume a "first best" world. In this case, it is straightforward to conclude that the rate of return on consumption must be identical to that on capital. For a model in which the maximand is the discounted utility of consumption, the rate of return (R.O.R.) is:

$$R.O.R. = \rho + \theta g,$$

where $\rho$ = utility discount rate,
$\theta$ = elasticity of marginal utility, and
$g$ = growth rate of consumption.

The right-hand side is identical to the value that Cline calls SRTP (the social rate of time preference). We both agree that this represents the optimal rate of return on consumption, but we part company when it comes to investment goods. In a "first best" world, I see no reason to distinguish between the rate of return on consumption and on investment. He refers to a "shadow price" on capital, and states that this price is greater than unity, but does not define the constraints that lead to this price. This is not just an academic nicety. It is at the heart of the debate over prescriptive and descriptive views on the rate of return.

There is another point of difference between us. The original DICE model refers to a single-region view of the world. In Nordhaus' later work on RICE, he describes a multi-region model, and he employs Negishi weights to ensure that each region satisfies an intertemporal balance of trade constraint. In Nordhaus and Boyer (2000), the authors state that: "The welfare weights were chosen so that the shadow prices on the period-specific budget constraints – the social marginal utilities of income – are the same across regions in each period at the social optimum." (p. 112)

In MERGE, we have taken a simpler approach. We specify a uniform R.O.R. among all regions, and do not impose constraints on capital flows – either between regions or between time periods. Because of the different growth rates in individual regions, we compensate by adopting region-specific and time-specific values of $\rho$, the utility discount parameter. MERGE allows for non-zero interregional capital flows, but it

turns out that they are small. Like Nordhaus and Boyer, we employ a logarithmic utility function, and therefore set the elasticity of marginal utility, $\theta = 1$.

What are the values that we take for the R.O.R.? To parallel Cline's case (a prescriptive approach), we follow the assumption that this is a constant 1% per year throughout our planning horizon. Alternatively, as a descriptive (market-oriented) approach, we shall assume that the R.O.R. begins at 5% per year in 2000, and that it declines linearly to 3% by the horizon date of 2200. (A decline in the R.O.R would be consistent with a world in which there is an eventual slowdown of growth.) Now, what are the consequences of these two very different assumptions?

Perhaps the most important difference is the sensitivity to assumptions about the distant future. The prescriptive approach makes present decisions quite sensitive to distant-future uncertainties such as non-market damage costs. In the absence of near-term constraints on capital formation, the prescriptive approach also leads to an unrealistically rapid immediate buildup of capital. Most important for the climate debate, the prescriptive approach implies an immediate stabilization of global carbon emissions and a reduction of these emissions in the very near future. (See the bottom line labeled "prescriptive – optimal" in Figure 4.) By contrast, the descriptive assumption implies that optimal behavior will lead to only a gradual departure from the baseline (reference case) emissions path.

What are the consequence for mean global temperature? See Figure 5. With the reference case (topmost line), emissions keep rising. It should come as no surprise that mean global temperatures then keep rising over the next two centuries. With the bottom line (prescriptive rates of return – optimal balancing of costs and benefits), the temperature increase is limited to about 1.5º C. With the middle line (descriptive rates of return – optimal balancing of costs and benefits),- the temperature increase is higher, but eventually it stabilizes at about 2.5º C. Using market-oriented criteria does <u>not</u> lead to indefinite postponement of abatement. But it does delay taking costly immediate measures. Most of the abatement occurs during the period when technology has improved, and abatement becomes less costly. At that time, more countries will have a higher GDP, and will be more willing to help pay for abatement. This is the consequence of using market-oriented rates of return – rather than those that might be suggested by social planners. We should probably move toward greenhouse gas abatement in the long run, but at a more gradual pace than advocated by Cline.

What are the cost differences between the prescriptive and the descriptive approach? Perhaps the most vivid difference appears in the efficiency price (in a "first best" world, a carbon tax) assigned to CO2. With the discount rates suggested by the prescriptive approach, a high price is assigned to carbon abatement in the immediate future – about $300 per ton. With the lower discount rates suggested by the descriptive approach, we move toward a near-term efficiency price of only $12. The market-oriented ROR does not ignore the distant future, but it places less weight upon that future than does the prescriptive approach.

MERGE is designed to produce an "optimal" trajectory, but we cannot be sure that it incorporates the most reasonable estimate of either the costs or the benefits of abatement. Suppose that we were to adopt a higher estimate of the willingness-to-pay for non-market damages. Instead of a WTP of 2% for high-income countries, imagine that these functions were based on a WTP of 4% for avoiding a temperature rise of 2.5º. This has a discernible effect upon the solution. With a doubling of the WTP, the efficiency price of carbon rises, but it does not skyrocket. The tax moves to $24 per ton during the immediate future. And for the balance of our planning horizon, the tax continues to be about twice that when the WTP = 2%. Again, the tax rises at a rate that is consistent with a gradual departure from the reference case (status quo) emissions path. It is costly to do otherwise.

To summarize what has been said in this note: If we are to avoid an indefinite rise in the world's temperature, greenhouse gas emissions must eventually be driven down to low levels. It would be wise to undertake this move over the next few centuries, but not over the next few decades. Meanwhile, it is important to undertake the research and development that will facilitate the long-term move toward a low-carbon world.

*References*

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Nordhaus, W.D., 1991. "To Slow or Not to Slow: The Economics of the Greenhouse Effect", *The Economic Journal*, vol. 101, no. 6, pp. 920-37.

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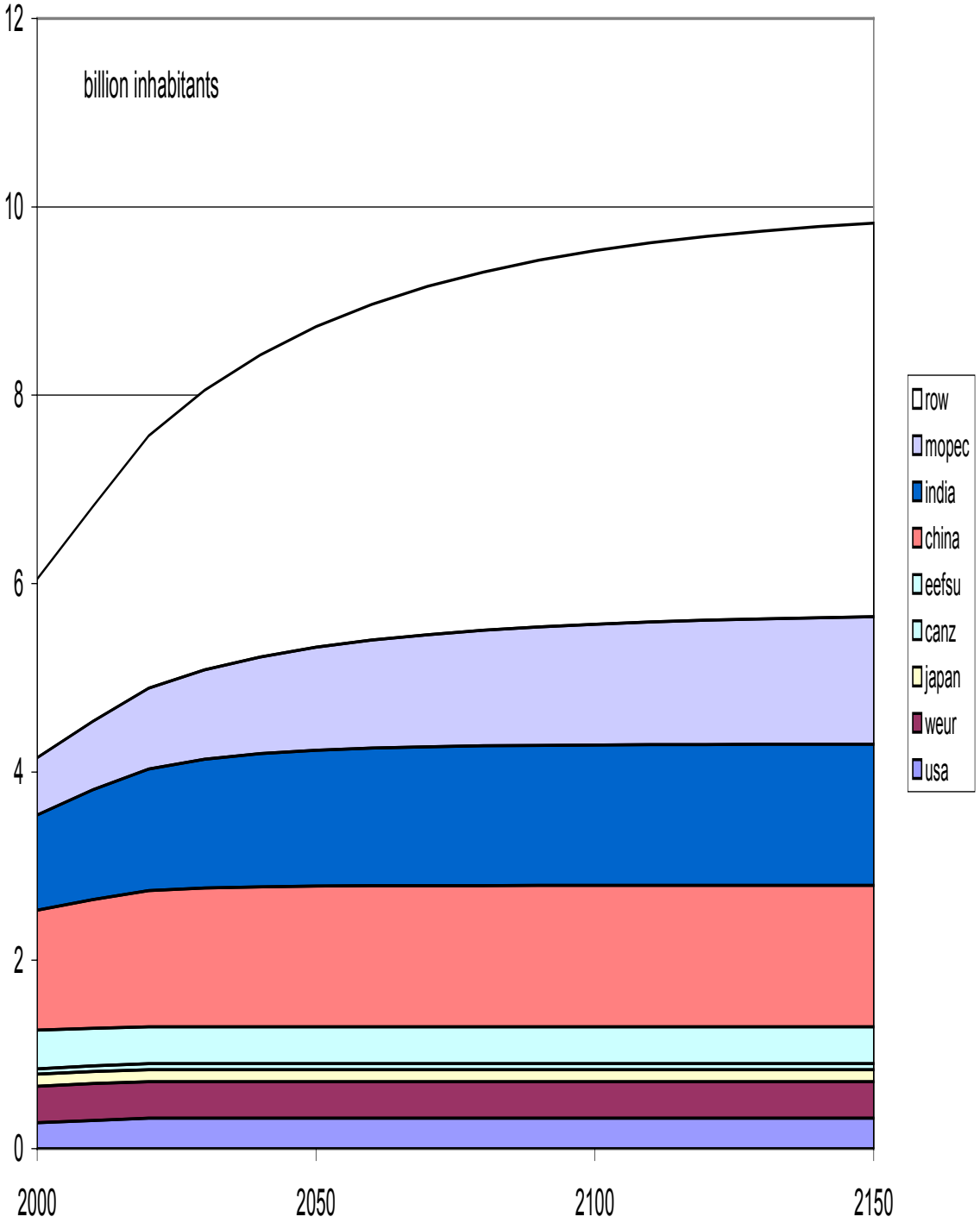
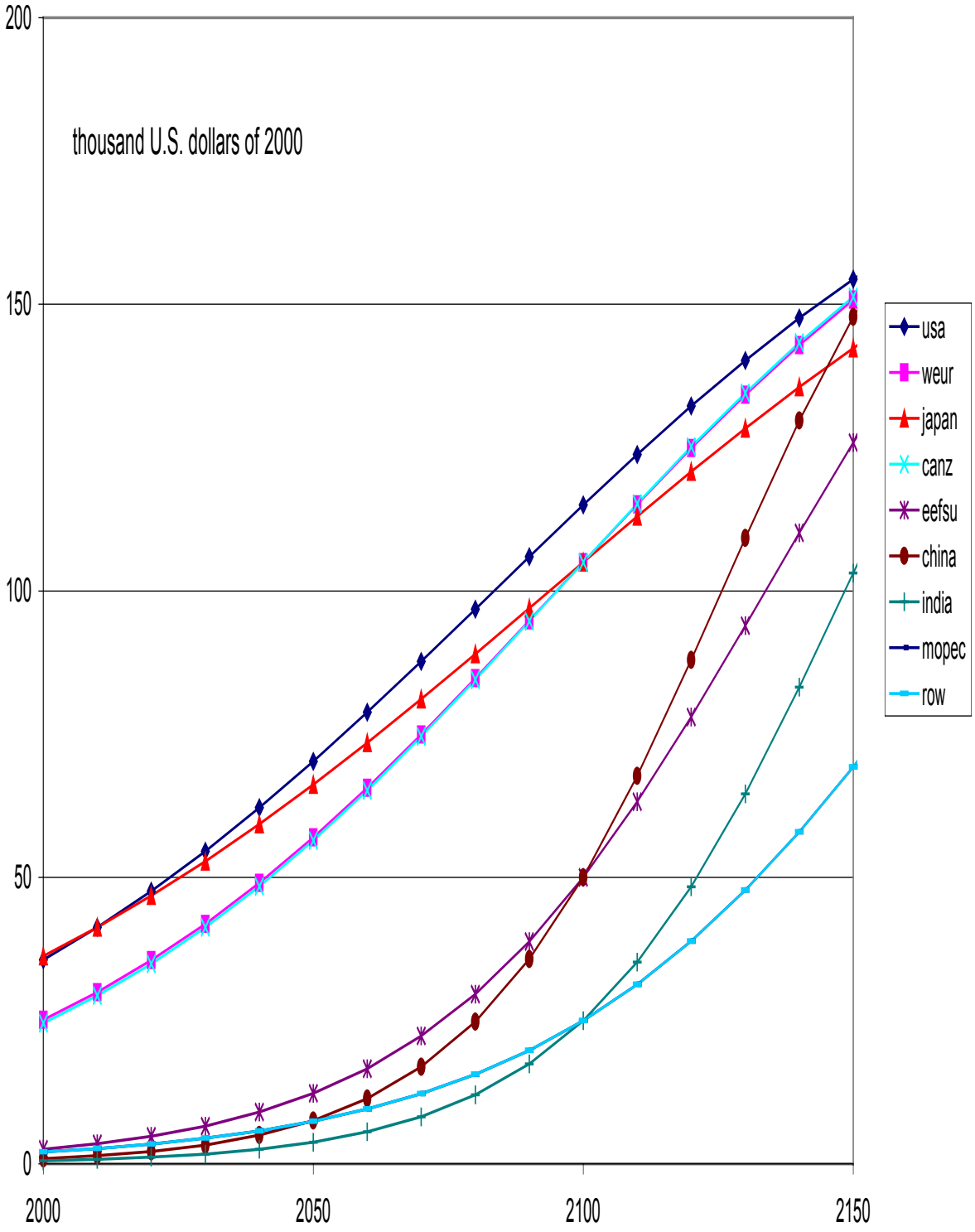
## Figure 1. Global and regional population



## Figure 2. Projections of GDP per capita - at market exchange rates



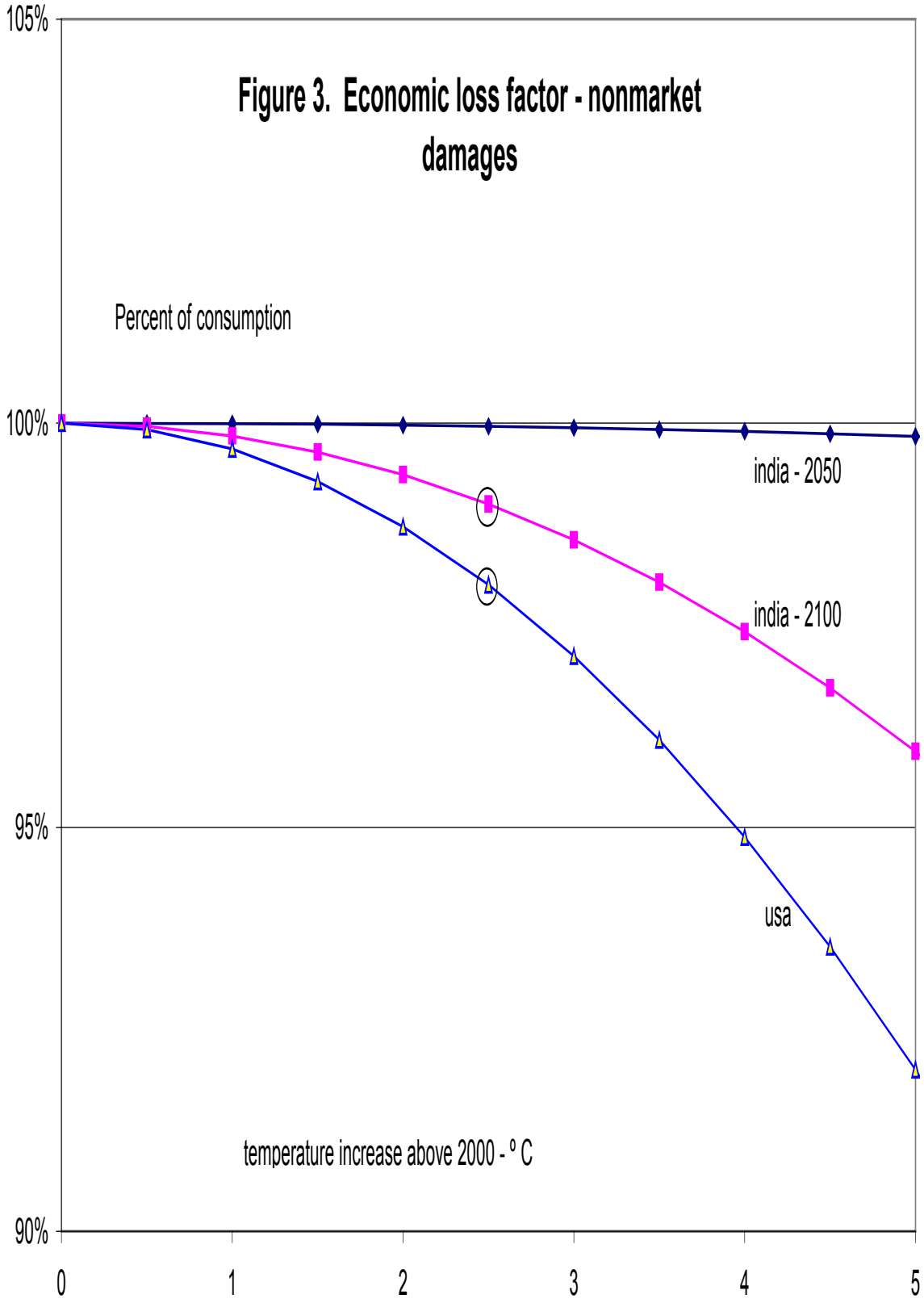
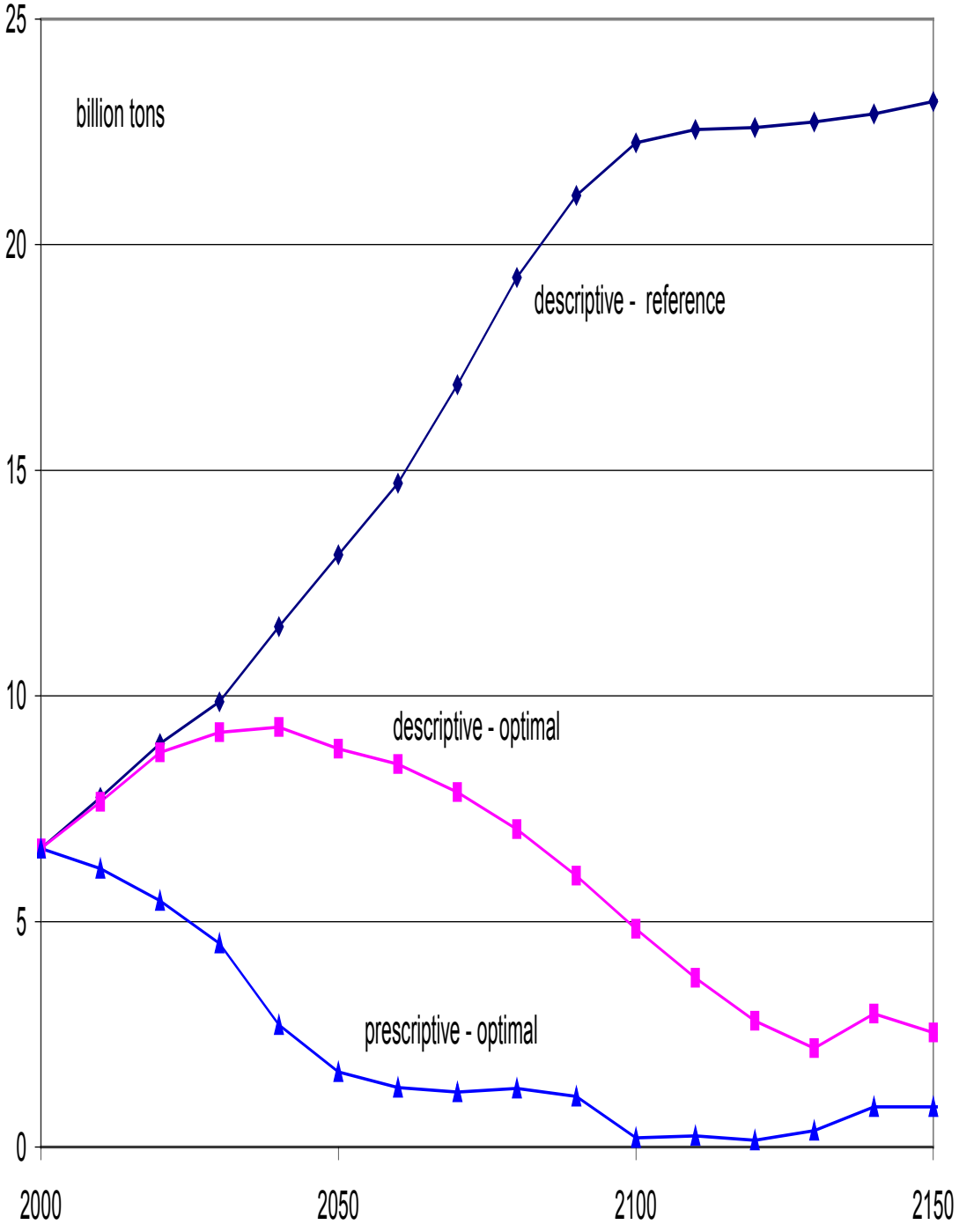


Figure 3. Economic loss factor - nonmarket damages
Percent of consumption
105%
100%
95%
90%
india - 2050
india - 2100
usa
temperature increase above 2000 - ° C
0
1
2
3
4
5

**Figure 4. Total carbon emissions - under alternative rates of return**



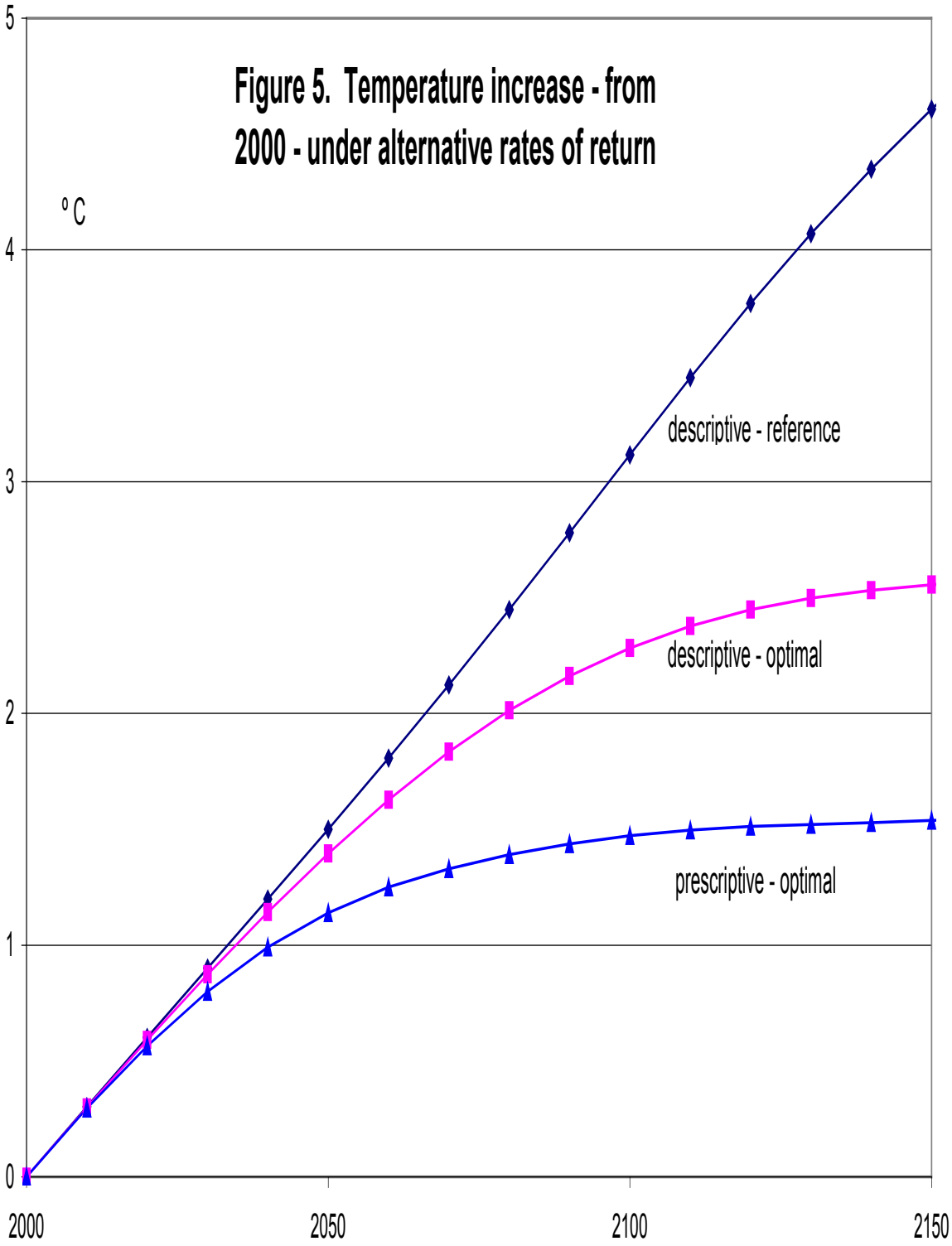


Figure 5. Temperature increase - from 2000 - under alternative rates of return
°C
5
4
3
2
1
0
2000
2050
2100
2150
descriptive - reference
descriptive - optimal
prescriptive - optimal

## Figure 6. Efficiency price of carbon

